Benefit-Cost Analysis of Curve Safety Treatments

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B/C Analysis

• B/C analysis encouraged by TxDOT HSIP
  • HSIP calls the ratio a Safety Improvement Index (SII)
    • SII accounts for:
      • increased traffic over projected life
      • changes in maintenance costs
      • amortization over long service lives
    • SII only uses injury and fatal crashes
      • (PDO crashes cost less anyway)
  • Ratio greater than 1.0 is cost-effective

The SII formula is as follows:

\[ S = \frac{R(C_F F + C_I I)}{Y} - M \]

\[ Q = \left( \frac{A_a - A_b}{A_b} \times L \right) S \]

\[ B = \frac{S + \sqrt{2} Q}{1.06} + \sum_{i=2}^{L} \left[ \frac{(S + \sqrt{2} Q) + (i - 1)Q}{(1.06)^i} \right] \]

\[ SII = \frac{B}{C} \]
Calculate Value of Reduced Crashes (Benefit)

- Estimate number of reduced crashes over the life of the treatment
- Multiply by cost of crashes
  - Most weight for crash costs comes from fatalities
  - $9.4M for fatal crash (USDOT)
  - $28,000 for crash with minor injuries
- Cost of an “average” crash on a curve: ~$190,000
  - A reduction of just a few crashes can be very cost-effective if the treatment is (relatively) inexpensive
TCDs on Curves
TCDs on Curves

- NCHRP study evaluating traditional devices (NCHRP 03-106; publication in progress)

- Cross-sectional study in 4 states (Florida, Ohio, Oregon, Tennessee)

- 541 rural sites
  - 271 isolated curves
  - 270 curve series

- 3 years of data
  - 1,623 site years (3 × 541)

- Generated CMFs from crash prediction models
Treatment Costs

- Survey results (averages) from 23 state DOTs

<table>
<thead>
<tr>
<th>Treatment (qty. per curve)</th>
<th>Material Unit Cost</th>
<th>Installation</th>
<th>Total Cost</th>
<th>Service Life (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance Warning Signs (2)</td>
<td>$136</td>
<td>$488</td>
<td>$760</td>
<td>11.9</td>
</tr>
<tr>
<td>Advisory Speed Plaques (2)</td>
<td>$47</td>
<td>N/A</td>
<td>$94</td>
<td>11.9</td>
</tr>
<tr>
<td>Chevrons (12, 6 per direction)</td>
<td>$91</td>
<td>$1,368</td>
<td>$2,460</td>
<td>11.1</td>
</tr>
<tr>
<td>Large Arrow (2)</td>
<td>$150</td>
<td>$335</td>
<td>$635</td>
<td>11.4</td>
</tr>
<tr>
<td>Delineators (8)</td>
<td>$24</td>
<td>$317</td>
<td>$509</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Does not include maintenance costs
Crash Reductions due to Curve TCDs

• Start with predicted crash frequency from HSM
  
  \[ N = \left( (2.67 \times L) + \frac{138}{R} \right) \times \frac{AADT}{10,000} \]

  \( N \) = annual predicted crash frequency at a curve,
  \( L \) = curve length (mi),
  \( R \) = curve radius (ft), and
  \( AADT \) = annual average daily traffic (veh/day),

• Apply crash reduction factor due to TCDs
  
  • Reduced Crashes = \( N \times (1 - CMF) \)

  • \( CMF_{Advanced\ Sign} = e^{0.71 - \frac{636}{R}} \)

  • \( CMF_{Chev\ or\ Large\ Arrow} = e^{0.203 - 0.89 \times \left( \frac{AADT}{10,000} \right)} \)
CMFs (#1)

- CMF of chevrons / large arrows at isolated curves
- The TCDs are more effective with higher volume
CMFs (#2)

- CMF of advance warning signs at isolated curves
• Crash Reductions Dependent Upon:
  • Curve Radius
  • Curve Length
  • ADT
  • TCD treatment

• The present value of a treatment for a site can be estimated using the above variables, reasonable growth factors and discount rates, and an average service life
Example of Present Value: Chevrons

Assumptions:
ADT=6,000 vpd
curve deflection = 90°
Example of Present Value: Warning Sign

Assumptions:
ADT=6,000 vpd
curve deflection = 90°
B/C Ratios for Curve TCDs

Assumptions:
ADT=6,000 vpd
curve deflection = 90°
High-Friction Surface Treatments
High-Friction Surface Treatments

- Reduces horizontal curve road departures
- Polish resistant aggregate in polymer resin binder
Data Collection

• Contract and bidding documents
• Roadway geometry
• Traffic characteristics
• Crash statistics
  • 5-yrs before HFST, and after HFST up to present
  • Exclude crashes outside HFST limits
  • Exclude crashes during construction
  • KABCO coding

\[
\text{Crash per million vehicles} = \frac{\text{Crashes}}{\text{year}} \times \frac{\text{AADT} \times 365}{1,000,000}
\]
Data Analysis

- **HFST Section Cost**
  - Normalized project cost
    \[
    \text{Cost ($)} = \text{Avg. Unit HFST Cost} ($/yd^2) \times \text{Area}(yd^2)
    \]

- **Benefit Calculation**
  - **Total Crashes** by KABCO (FDOT version)
  - **Total Crashes** by average crash cost ($195,000)
  - **Wet Weather** by average crash cost ($195,000)

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Cost Per Crash By Type (Thousands $)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K</td>
</tr>
<tr>
<td>Lost Quality of Life</td>
<td>$7,750</td>
</tr>
<tr>
<td>Economic</td>
<td>$1,400</td>
</tr>
<tr>
<td>Societal Impact (Total Cost)</td>
<td>$9,140</td>
</tr>
<tr>
<td>FDOT Societal Impact (Total Cost)</td>
<td>$10,000</td>
</tr>
</tbody>
</table>

- **Benefit-Cost.**
  - Average per section type
Project Data

- 38 sections w/ data
  - 16 tight curves
  - 16 wide curves/tangents
  - 6 intersections/intersection approaches

Mainline (Dev 333)
Bridge deck (TSP 403)
Crash Rates (Total Crashes)

- Tight Curves*: 1.00 (Before HFST), 0.62 (After HFST)
- Wide Curves / Tangents: 0.10 (Before HFST), 0.12 (After HFST)
- Intersections/Int. Approaches: 1.97 (Before HFST), 2.97 (After HFST)

* Radius <1,000ft
Crash Rates (Wet Weather Crashes)

- Tight Curves*: 0.59
- Wide Curves / Tangents: Before HFST 0.04, After HFST 0.03
- Intersections/Int. Approaches: Before HFST 0.51

* Radius <1,000ft

HFST Section Type
Normalized HFST Project Cost

- **Tight Curves**: $171,440
- **Wide Curves/Tangents**: $559,534
- **Intersections/Int. Approaches**: $475,864

* Radius <1,000 ft
Benefit-Cost

- **Total Crashes-FDOT KABCO**
- **Total Crashes-Avg.**
- **Wet Weather Crashes-Avg.**

* * Radius < 1,000 ft
*** From crash-reduction perspective
Benefit-Cost

**Diagram Description:**
- **Tight Curves:**
  - Average Benefit-Cost Ratio: 24.5
  - FDOT KABCO
  - Total Crashes-Avg.
  - Wet Weather Crashes-Avg.

**Notes:**
- * Radius < 1,000 ft
- ** Ratio not calculated (benefit is negative)
- *** From crash-reduction perspective
HFST Recommendations

- Continue promoting HFST for crash reduction around tight curves with a history of crashes.
- Reduce emphasis of safety benefits when considering HFST on wide curve/tangent sections that have no history of crashes.
- Evaluate benefit-cost of HFST as a maintenance treatment of concrete bridge decks.
- Evaluate in-detail the nature of crashes at intersection/intersection approach sections and whether the crashes are related to the installation of HFST.
Thank You.
Questions?

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